Journal of Water Process Engineering 25 (2018) 22–27

Contents lists available at ScienceDirect

Journal of Water Process Engineering

journal homepage: www.elsevier.com/locate/jwpe

Effect of pressure on desalination of MBR effluents with high salinity by using NF and RO processes for reuse in irrigation

M.C. Hacıfazlıoğlu[a,1], H.R. Tomasini[a,b], N. Kabay[a,*], L. Bertin[b], T.Ö. Pek[c], M. Kitiş[d], N. Yiğit[d], M. Yüksel[a]

[a] Ege University, Chemical Engineering Department, Faculty of Engineering, Izmir, Turkey
[b] Alma Mater Studiorum University of Bologna, Chemical Engineering Department, Bologna, 40126, Italy
[c] ITOB-OSB, Tekeli-Menderes, Izmir, Turkey
[d] Süleyman Demirel University, Environmental Engineering Department, Faculty of Engineering, Isparta, Turkey

ARTICLE INFO

Keywords:
Agricultural irrigation
Membrane processes
Nanofiltration (NF)
Reverse osmosis (RO)
Wastewater reclamation
Water reuse

ABSTRACT

Clean water sources are quickly depleted since the industrial revolution due to climate change and overpopulation. Use of potable water for agricultural irrigation is under imminent threat. Therefore, it is important to obtain irrigation water from alternative sources such as industrial wastewaters. On the other hand, industrial wastewaters have to be treated well otherwise they can pollute the environment and decrease the irrigation potential of soil. Membrane bioreactor (MBR) effluents of industrial wastewaters have a great potential to be used in agricultural irrigation. In this study, the permeates of NF270 and BW30-RO membranes were produced from MBR effluent discharged from Wastewater Treatment Plant of ITOB Organized Industrial Zone, Menderes, Izmir. They were evaluated for their reuse in agricultural irrigation. While doing this evaluation, effect of operating pressure on water quality was also investigated. It was found that the RO permeate is not suitable to reuse in irrigation. On the other hand, the NF permeate could be suitable for medium-salinity tolerant plants.

1. Introduction

Climate change, industrialization and overpopulation deplete fresh water sources, especially in arid or semi-arid regions such as North Africa, the Middle East, Australia [1]. Agricultural demand for potable water is stated more than 70% of water withdrawal by Food and Agricultural Organization (FAO) in 2016 [2]. The use of wastewater for agricultural irrigation may decrease the amount of used potable water yet it would increase salinity, damage soil quality and crop development [3]. Wastewater reclamation may be a good choice for this problem.

Membrane bioreactor (MBR) is a process combining biological treatment with membrane filtration in a bioreactor. It has superiority over conventional activated sludge system (CASS) since it does not include sedimentation unit and gives less sludge production, higher total suspended solid (TSS) rejection and smaller footprint [4]. Since MBR effluent quality is higher than CASS effluent, it can be evaluated for the irrigation. Nanofiltration (NF) and reverse osmosis (RO) processes can be used as post-treatment after MBR process to produce water for agricultural irrigation.

It is suggested that pressure-driven membrane processes can be used to treat secondary effluent of industrial wastewater in order to reuse it in agricultural irrigation since these membranes are capable of removing various monovalent and divalent ions from the solution and therefore can reduce salinity in water greatly. There are various studies on the application of NF and RO processes for reclaiming wastewater in order to reuse in agricultural irrigation [5–7]. Bunani et al. [6] experimented with AK-BWRO and AK-SWRO membranes for municipal wastewater reclamation. Their findings indicated a certain blend ratio of the secondary treated municipal effluent and RO permeate can be used for agricultural irrigation. Shanmuganathan et al. [5] also suggested a blend of NF and RO permeates when they worked with NP-010, NP-030 NF and WC-RO membranes.

RO process is cost effective since phase change does not occur unlike thermal treatment processes [8]. RO process is the most-widely used desalination method for brackish water and seawater today and applications of the RO process are various, mostly focused on purification and concentration. RO process is also used as a pre-treatment process for production of high pressure boiler feed water or ultrapure water, applied before electrodeionization (EDI) or ion-exchange [9].

* Corresponding author.
E-mail address: nalan.kabay@ege.edu.tr (N. Kabay).
[1] Present address: Istanbul Technical University, Chemical Engineering Department, Turkey.

https://doi.org/10.1016/j.jwpe.2018.06.001
Received 2 March 2018; Received in revised form 17 May 2018; Accepted 3 June 2018
Available online 14 June 2018
2214-7144/

Nomenclature

A (m^2)	Membrane area
C_f	Feed parameter value
C_p	Permeate parameter value
C, C (L/m^2 h)	Concentrate stream, concentrate flux
F, F (L/m^2 h)	MBR effluent, MBR effluent flux
P, P (L/m^2 h)	Permeate stream, permeate flux
R (%)	Rejection of any parameter
V_c (L/min)	Concentrate flowrate
V_p (L/min)	Permeate flowrate
WR (%)	Water recovery

Main model of the mass transport in a NF membrane is represented by Donnan steric pore model and dielectric exclusion [10]. Since pores are not media for solute transfer in dense membranes such as RO membranes, main causes of mass transfer for RO membranes are size exclusion and charge exclusion [11]. This situation causes a significant flux difference between NF and RO membranes even though the quality of permeate is better for RO.

Dependency of permeate flux on the applied pressure for solution-diffusion transport mechanism is shown by Eq. (1) (Shenvi, 2015).

$$J_P = L_P * (\Delta P - \Delta \pi) \tag{1}$$

where J_P is the permeate flux, L_p is the water permeability (a specific characteristic of a membrane), ΔP is the pressure difference between two sides of membrane and $\Delta\pi$ is the osmotic pressure difference between feed and permeate solutions.

Although increasing pressure increases irreversible fouling due to compression of foulants [12], increased flux and better salt rejection are often desired.

The scope of this study was to investigate the effects of pressure on the produced permeate from NF and RO membranes and evaluation of the product water for reuse in agricultural irrigation.

2. Methods

2.1. System configurations and experiments

BW30-RO and NF270 membranes were used for this experimental study. Properties of these membranes are given in Table 1.

BW30-RO, product of Dow Filmtec™ is a polyamide thin film RO membrane and provides a high rejection stability even with high TDS in water. The NF membrane NF270 is also produced by Dow Filmtec™. MWCO of NF270 membrane is given between 200–400 Da. Average MWCO of NF270 is also determined by Rohani et al. as 330 Da ± 4 and by Kelewou et al. as 257 Da ± 15 [13,14].

Studies were performed for a period of 4 h under the applied pressure of 10 and 20 bar for NF270, 20 and 30 bar for BW30-RO.

Permeate and feed samples were taken at each hour and analyzed for parameters related with irrigation quality. Concentrate and permeate flow rates are recorded in each half hour. Average results were used to obtain more reliable results.

Experiments were performed in a container laboratory where a mini pilot-scale membrane test system was placed in the wastewater treatment plant of ITOB Organized Industrial Zone at Menderes, Izmir, Turkey (Fig. 1).

Flow scheme of the membrane test system was given in Fig. 2.

2.2. Characteristics of the feed water

MBR effluent of the wastewater treatment plant of ITOB Organized Industrial Zone located in Menderes, Izmir (Turkey) was used as the feed solution for NF and RO membranes. After the treatment of industrial wastewater with MBR process as a secondary treatment, MBR effluent stream was collected in a 500 L of storage tank. The characteristics of the MBR effluent were given in Table 2.

2.3. Calculation of performance parameters

Water recovery is calculated for each measurement of permeate and concentrate fluxes by using Eq. (2).

$$\mathrm{WR}\,(\%) = \frac{J_P\,(\frac{L}{m^2 . h})}{J_F\,(\frac{L}{m^2 . h})} \tag{2}$$

Where WR is the water recovery and the feed flux (J_F) is the sum of permeate flux (J_P) and concentrate flux (J_C). Permeate flux is experimentally calculated by using Eq. (3).

$$J_P\,(\frac{L}{m^2 .\, h}) = \frac{Q_p\,(\frac{L}{min})}{A\,(m^2)} * \frac{60\,min}{1\,h} \tag{3}$$

Where Q_p is the permeate flow rate and A is the active membrane area (2.6 m^2). The concentrate flux is also calculated in the same way; by using V_c (concentrate flow rate) instead of V_p.

All permeate fluxes are normalized at 25 °C by using Eq. (4).

$$J_{P_{adj}} = \frac{J_P}{1.03^{(T-25)}} \tag{4}$$

Where $J_{P\ adj}$ is the adjusted flux normalized at 25 °C and T is temperature of permeate sample at which the tests are performed [15].

Observed rejection of any parameter is calculated by using Eq. (5).

$$R(\%) = \frac{C_f - C_p}{C_f} * 100\% \tag{5}$$

Where R is the observed rejection, C_f is the parameter value in the membrane feed stream and C_p is the parameter value in the permeate stream. Average rejections were calculated from average compositions of permeates and feed streams.

Sodium hazard is the effect of sodium ion on soil hydraulic properties, which can be identified by sodium adsorption ratio (SAR) factor and its calculation method is given in Eq. (6) [16]. SAR is used to compare the effect of sodium concentration of soil permeability by comparing it with divalent cation concentrations.

$$SAR = \frac{[Na^+]}{\sqrt{\frac{[Ca^{2+}] + [Mg^{2+}]}{2}}} \tag{6}$$

Potassium adsorption ratio (PAR) is a dimensionless parameter similar to SAR that shows the effect of potassium instead of sodium and it is calculated with the formula given in Eq. (7). Though there is no agreement of safe PAR value, water with a maximum PAR of 5 seems suitable to use in irrigation. All concentration units for SAR and PAR calculation are meq/L [17].

Table 1
Membrane properties (From Dow Datasheet for BW-30 RO and NF-270 membranes).

Membrane	Active Membrane Area (m^2)	Salt Removal (%)	Max Temperature (°C)	Max Pressure (bar)	pH Interval
BW30	2.6	99.5[a]	50	41	2-11
NF270	2.6	97.0[b]	45	41	2-11

[a] NaCl salt removal.
[b] $MgSO_4$ salt removal.

Fig. 1. Mini-pilot scale membrane test system.

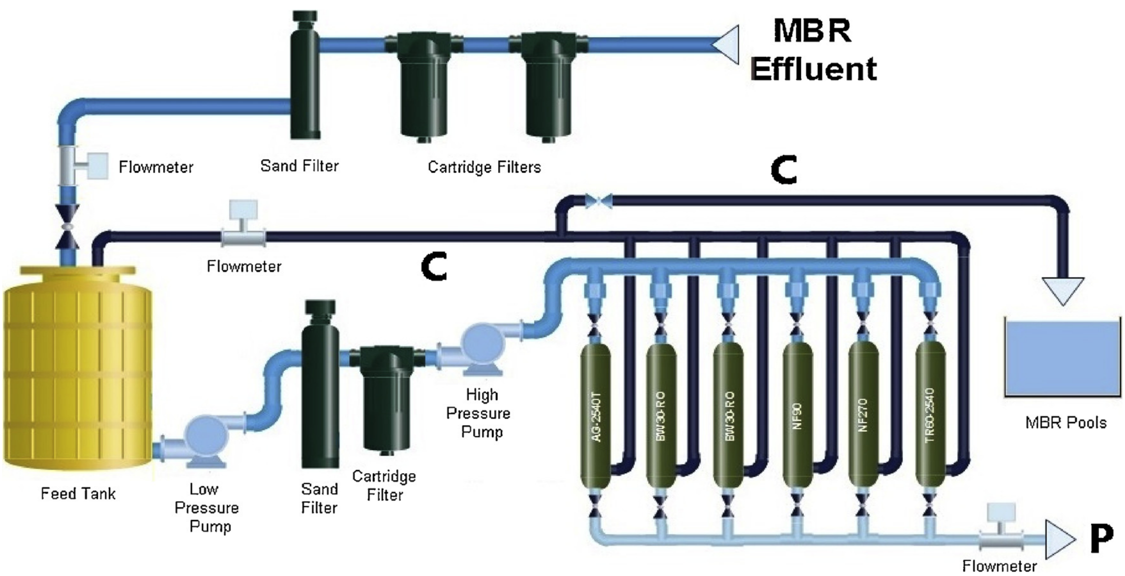

Fig. 2. Flow scheme of NF/RO secondary effluent treatment system.

Table 2
Properties of MBR effluent.

Parameters	Min-Max	Average
TDS (mg/L)	1910–2170	2093
TSS (mg/L)	0–9.75	4.40
Color (mg/L Pt-Co)	28.4–93.3	50.02
Turbidity (NTU)	0.47–2.93	1.33
COD (mg/L)	14.6–105	45.74
SiO_2 (mg/L)	6.28–9.55	7.39
HCO_3^- (mg/L)	20.7–36.3	28.1
Na^+ (mg/L)	492–763	606
Ca^{2+} (mg/L)	83.5–100	93.5
K^+ (mg/L)	280–366	334
Mg^{2+} (mg/L)	37.4–47.6	41.2
EC (mS/cm)	3.70–4.16	4.03
pH	6.97–7.53	7.27
SO_4^{2-} (mg/L)	494–659	559
Cl^- (mg/L)	566–904	701
TOC (mg/L)	7.55–46.0	28.7
Water Hardness (mg/L $CaCO_3$)	413–583	462
NO_3-N (mg/L)	6.53–93.9	60.3
NO_2-N (mg/L)	0.06–0.47	0.28
PO_4-P (mg/L)	0.18–0.34	0.27
NH_4-N (mg/L)	0.03–0.46	0.18
Total Nitrogen (mg/L)	21.7–91.3	55.6

Table 3
Evaluation of chemical quality of water for irrigation [18].

Parameter	Unit	Degree of Restriction on Use		
		None (Class I)	Slight to Moderate (Class II)	Severe (Class III)
Salinity				
EC	μS/cm	< 700	700–3000	> 3000
TDS	mg/L	< 500	500–2000	> 2000
Permeability				
SAR 0–3		EC ≥ 0.7	0.7–0.2	< 0.2
3–6		≥ 1.2	1.2–0.3	< 0.3
6–12		≥ 1.9	1.9–0.5	< 0.5
12–20		≥ 2.9	2.9–1.3	< 1.3
20–40		≥ 5.0	5.0–2.9	< 2.9
Specific Ion Toxicity				
Sodium (Na^+)	mg/L	< 70	> 70	
Chloride (Cl^-)	mg/L	< 100	> 100	
Boron (B)	mg/L	< 0.7	0.7–3.0	> 3.0

Table 4
Agricultural Irrigation Criteria [19,20,21].

Type	Parameter	Unit	Degree of Restriction on Use		
			None	Slight-Moderate	Severe
Salinity	Electrical Conductivity (EC)	mS/cm	< 0.7	0.7–3.0	> 3.0
	Total Dissolved Solid (TDS)	g/L	< 0.45	0.45–2.0	> 2.0
Nutrients	Nitrate-N	mg/L	< 5	5–30	> 30
	Total Nitrogen (TN)	mg/L	< 5	5–30	> 30
	Phosphate-P	mg/L	< 2 (< 5)		
	Potassium (PAR)	–	< 5	5–10	> 10
Ion Toxicity	Bicarbonate	mg/L	< 90	90–500	> 500
	Boron	mg/L	< 0.7	0.7–3.0	> 3.0
	Chloride	mg/L	< 106.5	> 106.5	
	Sodium	mg/L	< 69	> 69	
	Free Chlorine	mg/L	< 1	1–5	> 5
Other	Total Suspended Solid (TSS)	mg/L	< 50	50–100	> 100
	pH	–	6.0–9.0		
	Turbidity	NTU	< 2		

$$\mathrm{PAR} = \frac{[\mathrm{K}^{+}]}{\sqrt{\frac{[\mathrm{Ca}^{2+}] + [\mathrm{Mg}^{2+}]}{2}}} \tag{7}$$

2.4. Agricultural irrigation criteria

Table 3 shows the evaluation of chemical quality for irrigational water and includes standards stated by Ministry of Environment and Urbanization of Turkish Republic [18].

Table 4 includes data given in Table 3 and also some extra criteria stated by US Environmental Protection Agency (EPA), UN Food and Agriculture Organization (FAO), and World Health Organization (WHO).

Given SAR-EC data in Table 3 for determination of effect of irrigational water on soil permeability is visualized in graph (Fig. 3).

In Fig. 3, Class III area represents that this water may cause serious drop in infiltration and it is not useable for irrigation. In Class II area, this water may have some negative effects on infiltration but it can be used with caution. On the other hand, the water in Class I area will have no harmful effects on infiltration.

Table 5
Average permeate flux and water recovery values.

Experiment	Average Permeate Flux (L/m^2 h)	T (°C)	Normalized Flux (L/m^2 h)	Water Recovery (%)
NF270 – 10 bar	59.9	27.0	56.6	62.0
NF270 – 20 bar	96.8	22.6	104.1	71.4
BW30-RO – 20 bar	46.7	26.3	44.9	55.8
BW30-RO – 30 bar	70.1	25.8	68.2	60.8

Table 6
Percent rejections of some selected parameters by NF and RO membranes at different operating pressures.

Parameter	Rejection (%)			
	NF270 – 10 bar	NF270 – 20 bar	BW30-RO – 20 bar	BW30-RO – 30 bar
EC	37.2	42.4	97.6	97.8
TDS	38.6	43.5	97.8	98.0
Color	45.5	94.0	97.9	93.0
Turbidity	65.5	91.0	82.5	86.8
Na^+	52.3	93.5	97.0	98.0
Ca^{2+}	68.1	67.9	97.9	97.0
K^+	39.0	42.9	98.2	96.6
Mg^{2+}	81.8	86.8	99.0	98.7
Cl^-	25.0	60.0	96.8	97.7
TOC[a]	61.5	78.3	95.7	66.7
Hardness	77.2	79.4	95.0	95.9
TN	15.3	36.3	90.9	94.2

[a] Total organic carbon.

3. Results and discussion

Flux is increased by 38.1% for NF270, 33.4% for BW30 when the pressure was increased. Average permeate flux, temperature and water recovery values are given in Table 5 within the normalized flux values.

Increasing applied pressure critically improved the permeate flux especially for NF270 membrane. Accordingly, the percent water recovery increased with an increase in operating pressure. Both of these gains are essential for a membrane process, therefore increasing pressure seems applicable in this manner.

Rejection performance of NF270 and BW30-RO membranes for various parameters at different pressures were summarized in Table 6.

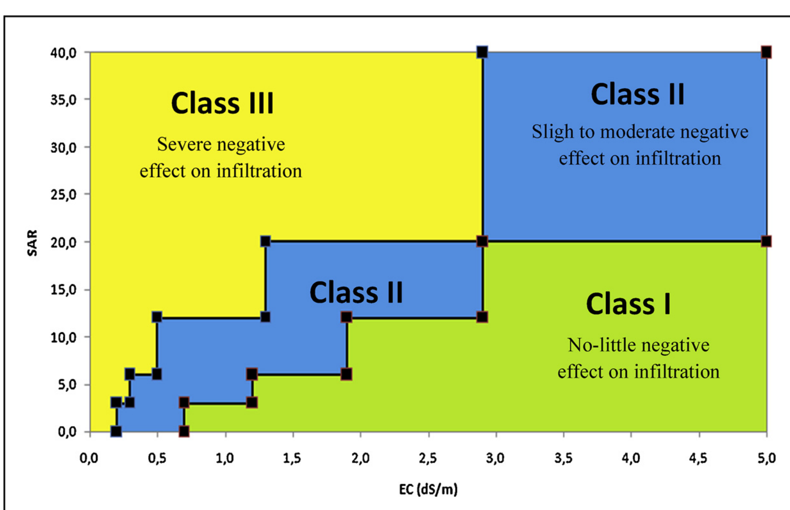

Fig. 3. SAR-EC classification of irrigation water regarding to effect on infiltration [18].

Table 7
Comparison of permeate qualities with irrigation standards.

Type	Parameter	Units	Permeates				Degree of Restriction on Use		
			NF270 10 bar	NF270 20 bar	BW30 20 bar	BW30 30 bar	None	Slight to moderate	Severe
Salinity	EC	mS/cm	2.61	2.13	0.11	0.08	< 0.7	0.7–3.0	> 3.0
	SAR	–	21.9	2.09	4.79	1.94	Check Fig. 3		
	TDS	g/L	1.33	1.08	0.05	0.04	< 0.45	0.45–2.0	> 2.0
Nutrients	NO_3-N	mg/L	8.70	45.7	3.06	5.29	< 5	5–30	> 30
	Total N (TN)	mg/L	18.4	63.1	3.43	7.97	< 5	5–30	> 30
	PO_4-P	mg/L	< 0.5	< 0.5	< 0.5	< 0.5	< 2		
	PAR	–	6.04	8.05	0.85	1.36	< 5		
Ion toxicity	HCO_3^-	mg/L	16.2	10.9	1.70	1.30	< 90	90–500	> 500
	B	mg/L	0.80	0.80	0.50	0.50	< 0.7	0.7–3.0	> 3.0
	Cl^-	mg/L	678	254	18.2	15.9	< 106.5	> 106.5	
	Na^+	mg/L	364	31.9	20.5	9.80	< 69	> 69	
	Free chlorine residual	mg/L	< 1	< 1	< 1	< 1	< 1	1-5	> 5
Others	TSS[a]	mg/L	2.6	0.0	3.0	0.0	< 50	50–100	> 100
	pH	–	6.8	7.2	5.6	6.9	6.0-9.0		
	Turbidity	NTU	0.39	0.04	0.51	0.11	< 2		

[a] Total suspended solid.

As shown in Table 6, percent rejections for various parameters did not change significantly for the BW30-RO membrane. But, increasing pressure from 10 to 20 bar strongly influenced the solute rejections by NF270, probably due to less contact time of solutes with membrane surface since the flux was nearly doubled. Especially, rejections of chloride and sodium ions were high and this makes the product water more suitable for agricultural irrigation.

It was seen that although most of the parameters make RO permeate more suitable for irrigation, its low conductivity together with its SAR values makes this water third class water due to decreasing soil permeability (Table 7).

Application of RO permeate directly for irrigation may create two problems:

- Very low mineral content due to its very high salt rejection would require extra remineralization step which might be unfeasible.
- The soil must be fertilized since RO permeate would decrease the soil permeability and thus prevent the plant to draw sufficient nutrients from the soil.

The opposite situation was obtained for NF270 permeate as it does not have any harmful effect on soil permeability but high concentrations of sodium and chloride in NF 270 permeate can be harmful to the plants. On the other hand, increasing pressure from 10 to 20 bar improved the quality of NF270 permeate by decreasing especially concentrations of sodium and chloride ions in the product water. This situation makes NF270 permeate obtained at 20 bar more suitable in agricultural irrigation for most of the plants except salinity-sensitive ones such as most of the fruit trees.

4. Conclusions

In this study, the effect of applied pressure on the permeate quality of BW30-RO and NF270 membranes was investigated and their suitability for agricultural irrigation. Permeate flux decline was not observed during 4 h of experimental period. When applied pressure was increased from 10 to 20 bar, solute rejections by NF270 increased. The permeate quality of RO membrane did not change much by the increase in applied pressure. A continuous test will be run in next studies in order to see the effect of applied pressure on permeate flux and quality.

The BW30-RO permeate was considered to be not suitable to reuse for irrigation due to its high SAR to EC ratio value. This indicates that BW30-RO permeate may have possible negative effects on soil properties. On the other hand, NF270 permeate can be used for plants that have a tolerance for medium salinity levels.

Working with NF270 membrane under 20 bar of operating pressure is a better option than operating at 10 bar since SAR value of NF 270 permeate decreased significantly with increasing pressure. On the other hand, regarding scale-up not only water quality but also specific energy consumption of the process and consequently treatment cost will be an important factor. This should be also taken into account.

Acknowledgments

Membrane test studies were performed at the Wastewater Treatment Plant of ITOB Organized Industrial Zone (ITOB-OSB) by the Industrial Thesis Grant Program (SAN-TEZ) given by the Ministry of Science, Industry and Technology of Turkish Republic (Project No.03.STZ.2013-02).

Acknowledgements are also given to the Scientific and Technological Research Council of Turkey (TUBITAK) for the scholarship awarded to M.C. Hacıfazlıoğlu (Project No: 114Y500) devoting some of his time for this project and European Union for the Erasmus + scholarship awarded to Horacio Reynaldo Tomasini.

We also thank to reviewers for their valuable comments and suggestions to improve the quality of this paper.

References

[1] D. Norton-Brandao, S.M. Scherrenberg, J.B. van Lier, Reclamation of used urban waters for irrigation purposes—a review of treatment technologies, J. Environ. Manage. 122 (2013) 85–98.
[2] Food and Agriculture Organization of the United Nations (FAO), Water NEWS: Climate Change & Water, (2016) (Accessed 09 March 2017), http://www.fao.org/nr/water/news/clim-change.html.
[3] V.R. Urbano, T.G. Mendonca, R.G. Bastos, C.F. Souza, Physical-chemical effects of irrigation with treated wastewater on Dusky Red Latosol soil, Ambiente Agua 10 (4) (2015) 737–747.
[4] F. Zanetti, G. De Luca, R. Sacchetti, Bioresource technology performance of a full-scale membrane bioreactor system in treating municipal wastewater for reuse purposes, Bioresour. Technol. 101 (2010) 3768–3771.
[5] S. Shanmuganathan, S. Vigneswaran, T.V. Nguyen, P. Loganathan, J. Kandasamy, Use of nanofiltration and reverse osmosis in reclaiming micro-filtered biologically treated sewage effluent for irrigation, Desalination 364 (2015) 119–125.
[6] S. Bunani, E. Yörükoğlu, Ü. Yüksel, N. Kabay, M. Yüksel, G. Sert, Application of reverse osmosis for reuse of secondary treated urban wastewater in agricultural irrigation, Desalination 364 (2015) 68–74.
[7] S. Bunani, E. Yörükoğlu, G. Sert, Ü. Yüksel, M. Yüksel, N. Kabay, Application of nanofiltration for reuse of municipal wastewater and quality analysis of product water, Desalination 315 (2013) 33–36.
[8] M. Shen, S. Keten, R.M. Lueptow, Rejection mechanisms for contaminants in

polyamide reverse osmosis membranes, J. Membr. Sci. 509 (2016) 36–47.
[9] I.G. Wenten, K. Khoiruddin, Reverse osmosis applications: prospect and challenges, Desalination 391 (2016) 112–125.
[10] S. Bandini, D. Vezzani, Nanofiltration modeling: the role of dielectric exclusion in membrane characterization, Chem. Eng. Sci. 58 (2003) 3303–3326.
[11] J. Radjenovic, M. Petrovic, F. Ventura, D. Barcelo, Rejection of pharmaceuticals in nanofiltration and reverse osmosis membrane drinking water treatment, Water Res. 42 (2008) 3601–3610.
[12] M. Xie, J. Lee, L.D. Nghiem, M. Elimelech, Role of pressure in organic fouling in forward osmosis and reverse osmosis, J. Membr. Sci. 493 (2015) 748–754.
[13] R. Rohani, M. Hyland, D. Patterson, A refined one-filtration method for aqueous based nanofiltration and ultrafiltration membrane molecular weight cut-off determination using polyethylene glycols, J. Membr. Sci. 382 (1–2) (2011) 278–290.
[14] H. Kelewou, A. Lhassani, M. Merzouki, P. Drogui, B. Sellamuthu, Salts retention by nanofiltration membranes: physicochemical and hydrodynamic approaches and modeling, Desalination 277 (1–3) (2011) 106–112.
[15] J. Mallevialle, P.E. Odendaal, M.R. Wiesner, Water Treatment Membrane Processes, McGraw-Hill, 1996.
[16] L.S. Severino, R.L.S. Lima, N. Castillo, A.M.A. Lucena, D.L. Auld, T.K. Udeigwe, Calcium and magnesium do not alleviate the toxic effect of sodium on the emergence and initial growth of castor, cotton, and safflower, Ind. Crops Prod. 57 (2014) 90–97.
[17] C.J. Smith, J.D. Oster, G. Sposito, Potassium and magnesium in irrigation water quality assessment, Agric. Water Manage. 157 (2015) 59–64.
[18] Notification on Technical Issues of Wastewater Treatment Plants, Ministry of Environment and Urbanization of Turkish Republic, 2010, pp. 91–93.
[19] World Health Organization (WHO), Water Quality for Irrigation, Table A1.1 (2006).
[20] Food and Agricultural Organization (FAO), Guidelines for Interpretation of Water Quality for Irrigation, Table 9 (1992).
[21] U.S. Environmental Protection Agency (EPA), Recommended Limits for Constituents in Reclaimed Water for Irrigation, Tables 2-7 (2004).